HAZARD CONTROL PLAN Renewal Cover Sheet

LANSCE Division

Title of Hazard Control Plan: **OPERATION OF THE LEAD-BISMUTH MATERIAL TEST LOOP** **Including unattended regime**
Hazard Control Plan Identification Number: LANSCE-3 HCP-18
Brief Description of Work: Same
Reviewer of the Plan (This HCP and the operating experience have been reviewed and no significant modifications are needed at this time): Valentina Tcharnotskaia (Name) — TSM (Title) — V Tcharnotskaia (Signature) — 6-11-03 (Date)
Initial Risk Estimate: ❒ Minimal ❒ Low ☒ Moderate ❒ High
Applicable Safety Permits Required to Perform Work: None
Residual Risk Estimate: ❒ Minimal ☒ Low ❒ Moderate
Work Authorization: Steve Wender (Name) — LANSCE-3 GL (Title) — Steve Wender (Signature) — 6/11/03 (Date)
Next Authorization Review Date: 06/11/04

LANSCE Division
Hazard Control Plan Cover Sheet

OPERATION OF THE LEAD-BISMUTH MATERIAL TEST LOOP Including unattended regime		
LANSCE-3 HCP-18	Revision: 2	Date: October 15, 2003
Location of Work: TA-53/ MPF-18		Group: LANSCE-3
Authors:	**Signature**	**Date**
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Initial Risk Level: Medium		
REVIEW/APPROVAL		
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Residual Risk Level: Low		
Approved by:		
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Next Authorization Review Date: April 17, 2003		

Table of Contents

HAZARD CONTROL PLAN
LAUR 02-3349

Development of Lead-Bismuth Target Applications (DELTA) Loop.

1. Definition of Work

A molten Lead-Bismuth Eutectic (LBE) test loop has been built to study corrosion and thermohydraulics of the liquid metal. Molten LBE is a promising spallation neutron target material for Accelerator Transmutation of Waste and other high-power applications. In this facility, LBE is melted in a melt tank and then transferred to the pump sump tank and to the loop by gas pressure. The pump is activated to create flow in the loop. Alternatively, lead-bismuth is circulated in a free convection mode, without the mechanical pump. The temperatures, fluid levels and flow speeds are monitored and controlled from a computer using a program written in LabView. **Personnel are not required to be present when liquid metal is circulated through the loop.**

The test loop (DELTA) is located at the north end of the high bay area of MPF-18. The loop is shown in Figure 1 without the supporting I-beam structure or the containment box. Operation of the loop is described in detail in the DELTA Operating Procedures. In summary, the operating procedure is as follows:

1) Preheat the system to the desired temperature for filling, typically 200 to 350ºC, including melt tank.
2) Evacuate the system to rough vacuum or vent down to about 2psig.
3) Open pneumatically actuated ball valves (transfer valves) between the loop and the melt tank.
4) Pressurize melt tank with He gas to transfer LBE to the loop up to desired level in the sump tank, typically 21 to 28 inches.
5) Close transfer valves and fill the loop into the expansion tank by further pressurizing the sump tank.
6) Turn on pump, slowly increasing the flow rate to desired level using variable frequency motor drive.

Depending upon the experiment in progress, the operators may:

1) Add and remove heat to operate with a temperature differential.
2) Inject gas (He-H_2 mix, He-O_2 mix, or steam) for oxygen control.
3) Adjust temperature, up to operating limits, which are as high as 540ºC in some parts of the loop.
4) Adjust pressure, up to maximum operating pressure of 90 PSIG.
5) Perform flow meter calibrations with calibration tank.
6) Turn off the pump and operate in a free convection mode using heaters and heat exchanger.
7) Disassemble the loop or its parts for inspection.

Facility interfaces:

1) Melt tank heater power. 45 kW at 440 V, with variable voltage power supply. Power set by operator via computer (LabVIEW based software).
2) Trace heaters for preheating the loop and temperature control. Nominally 50 kW at 220 V.
3) Main heater power. Nominally 80 kW at 220 V.
4) 110 V power to lights, computer, etc.
5) Cooling water to heat exchanger, motor cover, and water jackets for freeze plugs. Nominally 70 kW, room temperature supply water.
6) Building ventilation system, approximately 1.5 air exchanges per minute, coupled to system containment box.
7) Compressed air for pneumatically actuated valves (80 PSI).
8) He gas through building supply lines from bottle farm outside the building.
9) Pump power: 25 HP (18 kW) AC at 460 V.

The loop will operate up to full time during a normal working week. Regular maintenance and inspection is required.

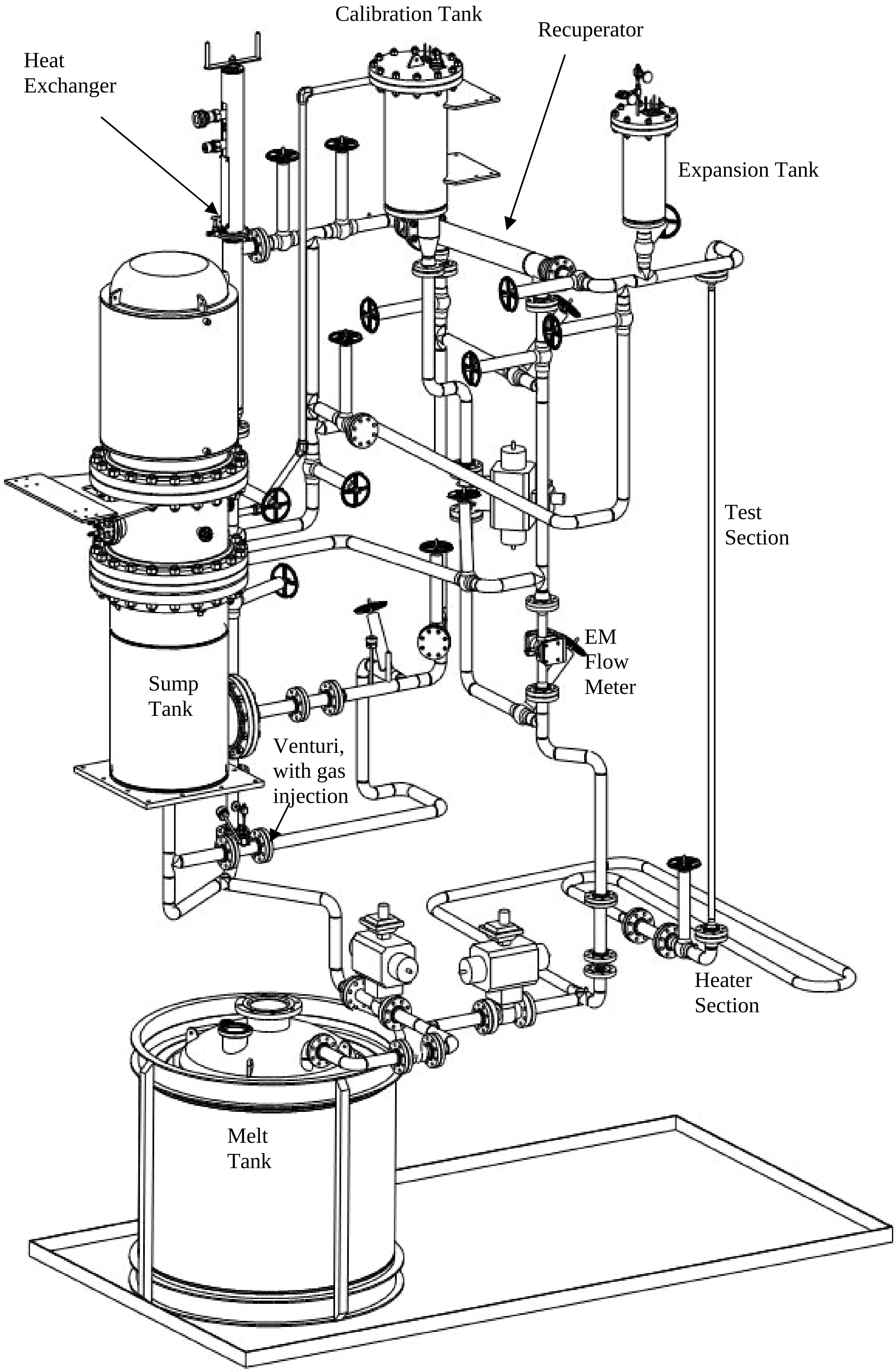

Figure 1. Illustration of the DELTA Loop.

2. Identification of Hazards

The hazards associated with this activity are:

Thermal (heat). There are heaters on the melt tank, sump and the loop piping. Operating temperatures are a minimum of 180ºC during operation, and as high as 525ºC. Thermal hazard may also be present in the event of an accidental spill of molten metal.

Electrical. Electricity provides power for the heaters, the pump motor and the instrumentation. Typical power and voltages are listed above.

Chemical. A primary constituent of the molten metal is lead, which is a toxic, RCRA-controlled substance. Approximately 3.5 tons of LBE (45% lead) will be inside the system. Lead oxide may be present during any maintenance or inspection operation that opens the piping or a vessel. Lead oxide may exist as a particulate that can become airborne.

Hydrogen and oxygen gases (each in a 6% solution with helium) will be used as cleaning gases for the DELTA loop. Hydrogen is flammable and oxygen is an accelerant, therefore, these gases represent potential fire hazards.

Bi dust/air mixture may ignite or explode under certain conditions.

Physical. There are physical hazards of a normal industrial nature: Crane use, forklift use, hand tools, power tools, ladders, etc.

Stored energy (pressure) The system pressure is controlled from weak vacuum (1 Torr) up to 90 PSIG, the design pressure at maximum operating temperatures. Pressure is maintained by pressurizing a helium or 6%hydrogen/ 94% helium cover gas.

3. Waste Streams

Operation and maintenance may generate small amounts of waste lead or lead oxide. Large quantities of lead that may be released will be reused. Small quantities will be disposed of. Any lead-oxide will also be disposed of. Other waste may include lead or lead oxide-contaminated rags, gloves, or other objects. The satellite accumulation area at the north side of MPF-18 will be used for storage of this waste. All waste storage and disposal will be conducted according to LANL and LANSCE policies under LANSCE waste coordinator guidance.

4. Initial Risk Level Determination

Based on LIG300-00-01.0, Safe Work Practices Implementation Guidance, the initial risk level is **MEDIUM.** The rationale for this initial risk level assessment is as follows:

- Thermal (heat). The accidental spill of molten metal has the potential to cause a major injury, however, the likelihood of such an occurrence is improbable. All piping and most vessel surfaces may be heated to temperatures as high as 540ºC during operation, which would cause injury in the event of contact. The probability of this event is low to medium. This combination of severity and likelihood results in a **medium** initial risk.
- Electrical. The electrical power and voltage used have the potential to cause a major injury, however, the likelihood of such an occurrence is improbable. This combination of severity and likelihood results in a **low** initial risk.
- Chemical. Lead contamination has the potential to cause occupational illness or environmental harm and the likelihood of such an occurrence is occasional. This combination of severity and likelihood results in a **medium** initial risk.

  Helium/hydrogen and helium/oxygen gas bottles are placed outside of the south side of the loop enclosure. An explosion or fire due to a hydrogen or oxygen reaction would cause injury, but the probability of such an event is improbable. Thus the risk in this case is **low**.

  Bismuth dust/air mixture may ignite or explode under certain conditions, which would cause injury, but the probability of this event is remote. Thus, risk in this case is **minimal**.
- Physical. The general physical hazards have the potential to cause major injuries; however, the likelihood of such an occurrence is improbable. This combination of severity and likelihood results in a **low** initial risk.

5. Hazard Controls

5.1 Thermal Hazard.

5.1.1 Eliminate the hazard. Heated surfaces are an unavoidable part of operations at temperatures up to 540ºC. The piping is insulated under normal operating conditions.

5.1.2 Design to reduce the hazard. Insulation is applied to most hot surfaces unless visual access to piping is necessary to assess performance and detect any leaks during maintenance or repair work.

5.1.3 Engineering controls. The entire loop is inside a containment box, which precludes incidental contact.

Heaters on the DELTA loop are controlled by a Data Acquisition and Control System (DAC). The DAC consists of a computer program running on LabView and several independent control devices. The DAC checks thermocouple readings throughout the loop and turns heating zones on and off according to corresponding temperature set points provided by the operator. The set points cannot be entered higher than the corresponding maximum temperatures. The DAC program includes checks for thermal emergency conditions such as overheating. All thermocouples are provided with corresponding maximum values in a table on “Presets” page of the DAC program’s front panel.

If any of the thermocouples’ readings are above the maximum value, the program activates SCRAM. SCRAM means that the power supply circuit to the pump, the heaters and the valves is interrupted. Power shut off causes the pump to stop, heaters to turn off and the liquid lead-bismuth to drain into the Melt Tank. All of the emergency conditions handled by the DAC program are shown on “DAC Critical Controls” list in Attachment 3.

In addition to the DAC program, a separate, independent temperature reading device monitors at least one thermocouple from every heating zone and checks it against the stored maximum value. If the reading is higher than maximum, the device causes SCRAM.

5.1.4 Warning devices. Signs will be posted around the enclosure during operations, stating:

WARNING

DELTA Loop is operating in unattended mode.

Extremely Hot Surfaces
Electrical Hazards
Stored Energy (pressure)

Lead Use Area
No eating or smoking

A list of system operators will also be posted with a warning that unless there is an emergency, no one else should be inside DELTA Loop fence without escort.

An Autodialer is installed at the DELTA loop. This device is connected to signals from various alarms such as SCRAM signal from computer or the independent temperature check devices. It will send alphanumeric pages to system operators assigned for the operation (see part 10 “System Operators and Cognizant Engineers”). The pages will include information on what condition caused the SCRAM.

5.1.5 Administrative controls. The general operating procedure for the DELTA Loop includes the procedure for entering the enclosure. Entry is made only if the inspection or other purpose of entry cannot be fulfilled from an open doorway.

Only designated System Operators may enter the enclosure when hot surfaces (>50ºC) or electrically energized equipment (heaters or pump) are present or when the loop is pressurized above 5 PSIG. All System Operators must have On the Job Training (OJT). OJT is described in part 6.

When hot surfaces or electrically energized equipment is present, PPE includes hardhat, safety glasses, gloves and safety shoes.

All Cognizant Engineers and System Operators must sign the Acknowledgement Log that is attached to this HCP.

SCRAM devices including SCRAM buttons, door interlocks, independent temperature checking devices and the DAC program SCRAM controls of temperature will be tested on an annual basis during scheduled maintenance periods.

Door interlock bypass keys will be removed from the bypass switch and kept in a different location on site during unmanned operations.

Only the Cognizant Engineer (see part 10 "System Operators and Cognizant Engineers") assigned to the specific operation can authorize changes to the maximum temperature values in the DAC program and in the independent temperature checking devices. This can be done only if:

- No new hazards are introduced.
- No existing hazards are exacerbated in any way.
- No hazard controls are circumvented or compromised in any way.

These changes will be recorded in the operation log.

During unmanned operations the loop will be attended at least once every 24 hours including weekends to check the operation. During that time the autodialer will be tested

5.2 Electrical Hazard.

5.2.1 Eliminate the hazard. Electrical power is required; associated hazards cannot be eliminated.

5.2.2 Design to reduce the hazard. Approved equipment and procedures are used.

5.2.3 Engineering controls. The entire loop is inside a containment box, which precludes incidental contact with resistance heaters. The melt tank heaters are fully enclosed. Ground fault interrupt devices protect personnel and equipment in the event of current leak to ground.

5.2.4 Warning devices. Signage as indicated in Section 5.1.4 will be posted.

An Autodialer (see 5.1.4) will send alphanumeric pages to system operators assigned for the operation (see the list in part 10 "System Operators and Cognizant Engineers") in case of an electrical SCRAM such as power failure in the building.

5.2.5 Administrative controls. All electrical work will be conducted according to LANL guidelines specified in LIR402-600-01.1, Tables 2.1, 2.2 and 2.3. Virtually all electrical work will be Mode 1 (non-energized). If work must be performed in Mode 2 or 3, an SEWP or HCP will be generated for that work.

Work on electrical equipment will be performed only by qualified, fully trained personnel. The 2-man rule is required, for work in Modes 2 or 3.

Lockout/Tagout procedures will be employed during all electrical work.

All workers have Electrical Training for the R&D worker or equivalent.

LANSCE-3 Electrical Safety Officer (ESO) will approve all electrical work and equipment.

During unmanned operations the autodialer will be tested when system operators are assigned for an operating period, at least once every 24 hours.

5.3 Chemical Hazard.

5.3.1 Eliminate the hazard. The chemical hazard is lead, which comprises 44.5% of the lead-bismuth eutectic. The use of LBE as a target material is the subject of this facility, so this hazard cannot be eliminated.

Hydrogen and oxygen gases are an essential part of corrosion control system in the DELTA loop and cannot be substituted. . (They may have to be used in unattended regime)

5.3.2 Design to reduce the hazard. DELTA loop was designed to contain lead-bismuth. The piping, the vessels and all joints follow the requirements of ASME Boiler and Pressure Vessel Code and Process Piping and Power Piping codes. Design calculations accounted for weight, pressure, thermal and seismic loads. The system was pressure tested before it was filled with lead-bismuth. Under normal operating conditions, no lead-bismuth is present outside of the piping and vessels of the loop.

A worst-case scenario spill accident is when the entire amount of lead-bismuth eutectic at 550^0C is dumped into the drip pan (see engineering controls below). In this case, some amount of lead vapor will be present above the surface of the liquid metal. Table 1 shows the lead vapor content as a function of temperature. The estimated vapor density at 550˚C is about 75 μg/m^3. This data is used with an assumption that the vapor is all lead, not lead-bismuth, to represent the worst-case scenario.

T (°C)	Vapor Pressure (Pa)	Vapor Density (μg/m^3)
235	1.30E-06	0.064
260	1.70E-06	0.079
270	7.00E-06	0.321
520	1.90E-03	59.64

Table 1. Lead vapor content. Lead-bismuth vapor is assumed to be all lead for this analysis. Experimental data from IPPE, Obninsk, Russia.

Calculations show that liquid lead-bismuth cools down to about 431˚C in the first 10 minutes after filling the drip pan. At 431˚C lead vapor density is below 13 μg/m^3. Lead-bismuth cools down to 300˚C in 2.5 hours. The calculated lead vapor density averaged over 8 hours is 1.6μg/m^3, which is well below the LANL action limit for lead exposure in air.

These calculations were made for the worst-case scenario accident without ventilation from the loop enclosure (see engineering controls below). In case of this extreme scenario, total calculated lead evaporated into the enclosure over eight hours is about 15 grams. This number was calculated for evaporation into vacuum without considering condensation or reabsorption. Air present inside the enclosure will promote lead vapor settling down and its reabsorption into the liquid metal. Also, the majority of this lead vapor falls back into the liquid lead-bismuth or condenses on cooler surfaces. The mean trajectory length of a lead atom under atmospheric pressure is a few millimeters. Not considering condensation, reabsorption or ventilation, however, the density of potential lead vapor inside the enclosure is higher than the LANL action limit. Administrative controls will be applied to the lead spill hazard that will include not entering the enclosure until the loop is cooled down to below 125^{o}C or until 12 hours has passed whichever takes longer. Calculations show that the full volume of lead-bismuth in the drip pan cools down to below the melting temperature in less than 12 hours. Spills that occurred during operations below 170^{o}C do not require waiting since vapor density at these temperatures is below the LANL Permissible Exposure Limit. Smaller spills of diameter of one meter or less should solidify after about thirty minutes. Operators can then enter the enclosure provided other hazards do not warrant exclusion.

No rotating seals are used. LBE is used in bulk form, sealed in vessels and piping with gas control that limits the content of oxygen to many orders of magnitude lower than that in air. This eliminates the presence of Bi dust/air mixture.

The LANL compressed gas supplier supplies hydrogen and oxygen in bottles standard for these gases under pressure. The partial pressure of the hydrogen and oxygen in their respective gas bottles is 6%. The bottles are installed outside of the south wall of the DELTA enclosure inside Building 18 or outside at the north side of the building. They are mounted upright using standard LANL gas cylinder fixtures. The air volume around the gas cylinders is large enough to provide adequate ventilation and to prevent flammable concentrations of hydrogen (from 4%) from accumulating. A special oxygen regulator is used.

We follow LANL gas cylinder safety regulations in handling these gases.

5.3.3 Engineering controls. The entire loop is inside a containment enclosure that prevents incidental contact with lead or lead oxide. The enclosure is based on a steel I-beam frame that is designed to withstand dead loads as well as seismic loads. Aluminum sheets are attached to the I-beams completely enclosing the loop.

The containment box is ventilated through the facility ventilation system, which filters exhaust air through HEPA filters prior to discharge. The fan in the ventilation system provides 34500 ft^3/min airflow at about 70% capacity. This flow rate provides approximately 1.4 air exchanges per minute inside the enclosure. The operating procedure includes checking for ventilation before starting. A pressure monitor is installed on the enclosure wall. Its reading is displayed on a gage on the enclosure and is monitored by the DAC computer. The DAC program stops operations automatically if positive differential pressure between outside and inside of the enclosure is not maintained.

A drip pan sized to hold 1.5 times the entire inventory of LBE covers the floor inside the containment box. Periodic air sampling and monthly surface swipes for lead contamination are conducted.

Any amount of Bi dust that may be created will be contained within the enclosure. It most likely will be mixed with black oxide powder that may be created inside the loop. Such powder substances outside the loop piping and vessels will be sprayed with water and collected using a HEPA vacuum cleaner and/or wet tissues as required for lead-contamination clean up. Thus, the probability of Bi dust fire is minimized. In the event of such a fire, administrative controls detailed below advise workers to let the fire burn out and to not approach it.

SCRAM buttons are placed at every entrance to the loop enclosure. If any conditions that warrant a shut down are observed, a SCRAM button will be engaged and the pump will stop, heaters will shut off and the loop will drain.

5.3.4 Warning devices. Signage shown in 5.1.4 is posted at all work area entry points during operations:

WARNING

DELTA Loop is operating in unattended mode.

Extremely Hot Surfaces
Electrical Hazards
Stored Energy (pressure)

Lead Use Area
No eating or smoking

A list of system operators will also be posted with a warning that unless there is an emergency no one else should be inside DELTA Loop fence without escort.

During operations that do not involve circulating lead-bismuth, a sign warning of lead hazard may be posted by itself.

When the level inside the Sump Tank or the Expansion Tank is below required for operation, or pressure is below required, a SCRAM occurs. Both of these conditions may indicate a leak of lead-bismuth. When a SCRAM occurs, the Autodialer will send alphanumeric pages to system operators assigned for the operation (see the list in part 10 "System Operators and Cognizant Engineers").

5.3.5 Administrative controls. When LBE is in the piping (full), the following

PPE

PPE is required for entry inside the enclosure: leather chaps and jacket, safety glasses, hardhat, face shield, thermally insulated gloves and safety shoes.

During normal operations, (that is not during maintenance and repair), in the event that an inspection reveals any black lead oxide powder in amount visible to the naked eye, the containment box will be vacated immediately and doors closed. The operation can continue if the oxide powder accumulation rate is slow. During draining, if the powder is around the hand valves that need to be opened, use the HEPA vacuum cleaner to clean it up and then open the valves. The system operators should consider wearing respirators for the cleanup depending on the amount of the oxide powder.

If a significant lead-bismuth spill takes place (at least a quarter of the drip pan floor is covered) workers will wait at least 12 hours before entering the enclosure.

If work with open piping or vessels previously containing lead-bismuth must take longer than an 8-hour period, ESH-5 will be called in to make a determination on necessary PPE.

PPE

During operations that involve opening pipes, if any black lead oxide powder is visible to the naked eye on the flanges or inside the pipe, the worker must wear a respirator.

When opening large vessels on the loop after more than 100 hours of operation since last opening, the worker must wear a respirator. If further inspection reveals no black lead oxide powder or other volatile powders of unknown nature visible to the naked eye, the worker may proceed without the respirator.

PPE

When opening any of the flanged connections on the loop piping or sensor connections workers must wear gloves, safety shoes, safety glasses and hard hats. If piping temperature is above 125^0C, thermal gloves and leather chaps must be used.

No work that involves opening of the pipes will take place at piping temperature above 200^0C.

Any ingress into the vessels or piping after initial operations shall be conducted by properly trained personnel. All workers will have lead awareness training. All System Operators will be on the lead surveillance program.

All System Operators must have safety shoes that are kept on site and used only for work in the DELTA area.

After handling lead one must wash his/her hands thoroughly. Do not eat, drink or apply cosmetics in the lead work area. Avoid introducing lead into the body.

During unmanned operations the autodialer will be tested when system operators are assigned for an operating period, at least once every 24 hours.

In the unlikely case of Bi dust/air fire the workers will stay away from the fire and let it burn out, which should happen within seconds. Water will be kept away from such fire, following the MSDS recommended procedure.

5.4 Physical Hazard.

5.4.1 Eliminate the hazard. Elimination of physical hazards is not possible. Use of cranes, hand tools, power tools, ladders, etc. is part of normal operation and maintenance.

5.4.2 Design to reduce the hazard. Use of cranes, hand tools, power tools, ladders, etc. cannot be reduced further.

5.4.3 Engineering controls. None.

5.4.4 Warning devices. Workers in the area are briefed on physical hazards. Special controls are implemented when necessary, such as vacating the area of nonessential personnel when overhead crane work is in progress.

5.4.5 Administrative controls. Equipment such as cranes and forklifts are used only by properly trained personnel. PPE inside the enclosure may include hardhat, safety glasses, full-face shield, and safety shoes. Good housekeeping practices will be enforced to minimize hazards.

PPE

5.5 Stored energy (pressure) hazard.

5.5.1 Eliminate the hazard. The system must be pressurized to operate.

5.5.2 Design to reduce the hazard. The system has been designed to ASME Boiler and Pressure Vessel Code, Process Piping and Power Piping codes. Maximum operating pressure is limited to 90 PSIG. Pressure relief valves set at 120 PSIG protect the system and personnel.

5.5.3 Engineering controls. The containment box provides a physical barrier between personnel and pressurized systems. Pressure checks of all vessels have been performed to 250 PSIG by an independent laboratory. The entire system has been pressure and leak checked to 120 PSIG at room temperature.

Pump maximum speed is limited to 40 Hz so as to not exceed 90 psig in the loop. The limits are applied in the DAC program and in the Allen-Bradley motor drive that controls the pump motor.

SCRAM buttons are placed at every entrance to the loop enclosure. If any conditions that warrant a shut down are observed, a SCRAM button can be engaged and the pump will stop, heaters will shut off, and the loop will drain.

5.5.4 Warning devices. Signage as indicated in Section 5.1.4 will be posted.

An Autodialer will send alphanumeric pages to system operators assigned for the operation (see the list in part 10 “System Operators and Cognizant Engineers”) when a SCRAM is activated due to pressure above maximum.

5.5.5 Administrative controls. Access to the containment box while the loop is pressurized is limited to System Operators. System Operators must have completed Low Pressure Systems Training, Intermediate and High Pressure Safety Training and Gas Cylinder Hazards Training. System Operators must have had OJT as described in 6.

Only the Cognizant Engineer (see part 10 “System Operators and Cognizant Engineers”) assigned to the specific operation can authorize changes to the maximum pressure values in the DAC program. This can be done only if:

- No new hazards are introduced.
- No existing hazards are exacerbated in any way.
- No hazard controls are circumvented or compromised in any way.

These changes will be recorded in the operation log.

Pressure relief valves will be checked annually and replaced as necessary.

PPE requirements are in 5.3.5.

During unmanned operations the autodialer will be tested when system operators are assigned for an operating period, at least once every 24 hours.

6. Skills, Training and OJT Requirements for Workers

All System Operators must have completed training required to work at Los Alamos National Laboratory and at Los Alamos Neutron Science Center
In addition all System Operators must have completed the following:

Laboratory Training:
1. Hazard Communication Introduction.
2. Lead awareness.
3. Gas Cylinder Hazards.
4. Pressure Safety Orientation.
5. Low Pressure System Training.
6. Intermediate and High Pressure Systems Training.
7. Non-energized electrical worker training.
8. Ladder Safety.

The list of System Operators is provided on a signature sheet in the documents folder.

All System Operators who enter the containment box during operations or during maintenance and inspection that requires opening the loop at any point must be on the lead surveillance program.

All workers involved with this operation must have completed the following On-the-Job Training:

a. Read HCP and test procedure.
b. Obtain authorization by a Lead Engineer, who has described the system according to the steps below and its operation to the Operator, and who acknowledges the Operators knowledge and understanding of the facility and its operation.
    1. DELTA loop is a system built to generate a flow of liquid lead-bismuth.
    2. Main hazards: Lead; Pressure; Heat; Electricity.
    3. PPE for different operations.
    4. Meaning of the warning signs.
    5. Description of the operation.
    6. Main functions of the DAC program.
    7. Inspection: first through portholes, then from the entrance and then if necessary from inside.
    8. Actions in case of SCRAM.
    9. Questions.
c. Sign the acknowledgment log (last page of this HCP).

APPLICABLE INSTITUTIONAL REQUIREMENTS

LIR 300-00-01.3, Safe Work Practices

LIR 300-00-02.3, Documentation of Safe Work Practices
LIR307-01-01.2, Safety Self-Assessment
LIR402-100-02.0, Hazardous Waste Operations and Emergency Response Training Requirements
LIR402-510-01.0, Chemical Management
LIR402-600-01.1, Electrical Safety
LIR402-1000-01.0, Personal Protective Equipment
LIR402-1110-01.1, Forklifts and Powered Industrial Trucks
LIR402-1200-01.1, Pressure, Vacuum, and Cryogenic Systems
LIR404-00-02.3 General/Waste Management Requirements
LIR404-00-03.1, Hazardous and Mixed Waste Requirements for Generators
LIR402-840-01.0, Welding, Cutting, and Other Spark-/Flame-Producing Operations

LPR 300-00-01, Integrated Safety Management
LIG300-00-01.0, Safe Work Practices Implementation Guidance
LIG402-1200-01.0, Compressed Gasses
LIG402-1200-03.0, Gaseous and Liquid Hydrogen
LIG404-00-03.0, Waste Profile Form Guidance

AR 13-2, Cranes, Hoists, Lifting Devices, and Rigging

These documents can be viewed on-line at http://labreq.lanl.gov/hdir/labreq.html and select "Master Index by Document Number" link.

7. Residual Risk Determination

Residual risk is **LOW.** The rationale for this residual risk level assessment after implementing controls is as follows:

- Thermal (heat). The accidental spill of molten metal has the potential to cause a major injury, as well as inadvertent contact with hot surfaces, however, with the administrative and engineering controls in place, the likelihood of such an occurrence is now remote. This combination of severity and likelihood results in a **low** residual risk.
- Electrical. The electrical power and voltage that are being used have the potential to cause a major injury, however, the likelihood of such an occurrence is now remote. This combination of severity and likelihood results in a **minimal** residual risk.
- Chemical. Lead contamination has the potential to cause occupational illness or environmental harm and the likelihood of such an occurrence is now remote. The controls in place significantly reduce the likelihood of this occurrence but because of long-term operation and possibly frequent ingress to the piping and vessels, this combination of severity and likelihood results in a **low** residual risk.

Hydrogen is flammable and oxygen is an accelerant, therefore, these gases represent potential fire hazards. The dilution of these gases with helium in addition to the controls in place reduce the probability of fire to remote and the hazard risk to **minimal**.

- Physical. The general physical hazards have the potential to cause major injuries, however, the likelihood of such an occurrence is now remote. This combination of severity and likelihood results in a **minimal** initial risk.

8. Procedures

Operational procedures are below.

DELTA LOOP OPERATING PROCEDURES

Last updated: October 15, 2003
LAUR 02-3348

These procedures are written to guide the DELTA Loop operations. Operators should familiarize themselves with the loop and the procedures before any operations. However, we do recognize that some of the operating features of the loop are not clear or well defined at this stage and unexpected situations may occur in such an experimental facility. Operators need to be vigilant and follow the prescribed safety principles when deviations from the procedures or emergency responses are called for. During emergency response, we will follow the order of importance as follows: personnel safety first, facility and environment second, and equipment third.

If during operations we identify procedural mistakes, unreasonable and/or unnecessary steps, unnecessary restrictions, or better procedures, we will record them in the DELTA Loop logbook and modify this procedure accordingly. In today's jargon, this procedure is a living document. Accordingly, the first step of the procedure authorizes the Cognizant Engineer in charge of the test in progress to deviate from written procedure if the deviation is properly logged, the loop is operating within the design envelope, no new hazards are introduced, no existing hazards are exacerbated, and no hazard controls are circumvented or compromised.

NOTE: These procedures are updated periodically as needed. Cognizant engineers should read procedures thoroughly for each operation.

Routine Inspection of the System

This procedure is applicable only during normal operating conditions.

1. Perform visual and audio survey of the enclosure for vibration, noise and heat indications.
2. Perform visual survey through the windows on the enclosure for LBE leaks or other problems.

   If a significant lead-bismuth spill takes place (at least a quarter of the drip pan floor is covered with the liquid metal) shut down and wait at least 12 hours before entering the enclosure.
3. Ensure the air temperature within the enclosure is below 50^{o}C by reading the thermocouples T102-103.
4. Wear proper PPE (see HCP) when opening the enclosure doors or entering the enclosure.

   When hot surfaces or electrically energized equipment is present, PPE includes hardhat, safety glasses, gloves and safety shoes.

   When in addition to above the piping is full of LBE add leather chaps and jacket, face shield and thermally insulated gloves.
5. Ensure ventilation system is on by observing that flaps at the ventilation duct entrances are sucked into the duct and moving.
6. Before opening enclosure doors turn the key on the SCRAM indicator panel to bypass position.
7. Perform visual and audio survey of the inside of the enclosure at the threshold of the door for signs of LBE or water leakage, presence of unusual powders (esp. if black), excessive vibration or heat, or loop components out of place (shifted, distorted or broken).
   - In the event that an inspection reveals any black lead oxide powder in amount visible to a naked eye, leave the enclosure and close the doors. The operation can continue if the oxide powder accumulation rate is slow. During draining if the powder is around the hand valves that need to be opened, use the HEPA vacuum cleaner to clean it up and then open the valves. Consider wearing a respirator.
   - If a significant lead-bismuth spill takes place (at least a quarter of the drip pan floor is covered) leave the enclosure and wait at least 12 hours before entering.
   - If a smaller LBE leak takes place, attempt to fix it if it is safe to do so, otherwise drain the loop and fix the leak.
8. Record any anomalies into the DELTA operations log book, including time and observer.
9. If a significant leak (see step 7) or broken pipes, vessels or supports are observed initiate a shut down procedure. Further work will follow "Maintenance and Repair Operation Inside of the Enclosure" procedure.

Pre-Start Checklist

1. Identify the Cognizant Engineer. Document the intent of the test and all special conditions or procedures in the logbook.
2. Check that all operators have read, understood all pertinent procedures and signed the HCP.
3. Check Personal Protective Equipment (PPE):
   a. Hardhat, safety shoes and safety glasses if inside enclosure.
   b. Items above plus face shield, leather chaps, leather jackets, and thermal gloves if molten LBE is in the loop.
4. Put up signage indicating high temperature, high pressure, and high voltage conditions exist inside the enclosure.
5. Turn strobe light on.
6. Check that the enclosure ventilation system is on by observing streamers at the 2 ventilation duct entrances. If fan is off, turn fan on and set to 60% power. Check the reading on the enclosure pressure gage. It should show a positive number greater than 0.5 mm of mercury.
7. Check He gas bottles for sufficient inventory. Pressurize the He supply line to the loop. Set regulator to100 psig, max.
8. Turn on water flow to all freeze plugs and the motor cover, if necessary. Open main supply line valve HV309 first, then slowly open main return line valve, HV310. For valve designations see Piping and Instrumentation Diagram in DELTA design drawings package. Check for leaks. If lines have been opened to air since the last use, perform the following water line purge procedure:
   a. Open main supply line valve, HV309.
   b. Bleed air from supply manifold using valve HV322 (close valve when finished).
   c. Partially open (slowly) motor jacket supply valve HV303. Maintain slow flow rate through to motor jacket until air is purged via air eliminator valve AE301. (Note: slow flow rate protects flow meter from damage.)
   d. When air is purged, open valve HV303 completely.
   e. Repeat this slow air purge process (steps c. and d.) with each of the freeze plug lines in succession (HV311, HV312, HV313, HV314).
   f. When air is purged from all lines, slowly open the main return line valve HV310.
   g. Check for leaks.
9. Drain and purge water from heat exchanger. Ensure HV301 and HV302 are closed. Open drain valve HV305. Slowly open compressed air valve HV321 to purge water from heat exchanger. Close HV321 when complete and leave HV305 open for venting purposes when heat exchanger is not in use.
10. Ensure that output signal power supply is connected to SSR power outlet inside DAC rack. It is a large white and black power plug marked “output”.
11. Cognizant Engineer specifies initial fill temperatures for the current operation and notes them in logbook. Verify that all set points are put into the DAC system. Verify that critical control values such as max temperatures are set to desired values. Only Cognizant Engineer can change critical control values

12. Turn on the computer and start DELTA control and data software. Specify data recording rate. Start SR630 independent temperature monitors.
13. Confirm all level sensors and thermocouples function properly. Level sensors should read circuit closed except melt tank level sensors LT109-112, which should indicate the presence of LBE up to 32”. Thermocouples should read temperature consistent with known condition of the loop. Confirm water flow to freeze plugs and venturi. Water flow sensors should read within their limits (see Instrumentation list)
14. Cognizant Engineer specifies valve positions for current operation and notes these in logbook. Operators verify actual valve positions. Suggestions for LBE fill follow:
    a. Open all 100-series valves except
        - HV116: calibration tank line
        - HV117: alternate test section inlet
        - HV118: alternate test section outlet
    b. Close all 200-series valves except
        - FV205: pressure equalization between melt tank and sump
        - FV208: pressure equalization between melt tank and expansion tank
        - HV212: flow restriction for solenoid bleed from expansion tank
        - HV214: flow restriction for solenoid bleed from melt tank
        - FV209: actuator valve for PT’s blow off gas valves

Normal Operating Procedure (Attended)

1. Perform all steps in "Before Start of Operations Checklist" above.
2. A designated Cognizant Engineer is responsible for each operating cycle for the DELTA loop. The Cognizant Engineer may deviate from this procedure at any time it is deemed necessary or desirable to achieve the goals of the operation in progress, provided the following conditions are met:
    a. No new hazards are introduced.
    b. No existing hazards are exacerbated in any way.
    c. No hazard controls are circumvented or compromised in any way.
    d. The deviation from procedure and the reason for the deviation are logged in the logbook and signed by the Cognizant Engineer.
3. Close all enclosure doors and verify that door interlock and SCRAM circuits are ready for power up.
4. Activate "LBE in Melt Tank" mode from pull-down menu on LabVIEW display.
5. Evacuate the loop. Turn on vacuum pumps VP201 and VP202. Open valves HV201 and HV202. Pump down to approximately –11 psig then close valves HV201 and HV202 and turn off vacuum pumps.
6. Preheat MTL and the melt tank as per requirements of the Cognizant Engineer. Use set points for heater zones in the DAC program to turn on heaters (except for venturi freeze plug heater HT535). For unattended preheating follow "Unattended Station Keeping Operation Procedure".
7. After preheating is complete, evacuate the loop one more time prior to transferring LBE by repeating Step 5.
8. Activate "Transfer" mode from pull-down menu on LabVIEW display.
9. Transfer LBE to sump:
    - Close FV205 and FV208 and FV209 pressure transducer standoff valve.
    - Open solenoid valve FV202 and needle valve HV204 to gradually increase the cover gas pressure inside the melt tank.
    - Monitor the decreasing level in the melt tank with LT109 through LT112, and the increasing level in the sump tank with LT101 through LT108.
    - Minimum sump fill for operation of the loop is 21 inches (LT106). For calibrations, minimum sump fill is 28 inches (LT108).
    - Monitor level sensors in the gas injection freeze plug. If LT131 (3^{rd} venturi level sensor) shows the presence of LBE, LabVIEW will display warnings and the fill operation must be terminated.
    - Stop the LBE transfer when the level inside the sump reaches the desired level by closing valve FV202. Then close drain valves FV101 and FV102.
10. Fill remainder of the loop from the sump:

- Pressurize the sump by opening FV201 and HV203.
- Monitor level decrease in sump.
- Fill loop until LT121 (3^{rd} level) in expansion tank indicates LBE.
- Close FV201.

11. Pressurize melt tank to approximately **38 psi above sump tank** pressure to prevent LBE leakage through solenoid valves. (This can be done simultaneously with the previous step.)

12. Close HV119 to isolate expansion tank from the rest of the loop while running pump. Configure loop flow path as desired.
13. Turn on the breaker to the pump controller.
14. Activate "Running" mode from pull-down menu on LabVIEW display.
15. Turn on the pump motor to circulate LBE in DELTA loop by clicking Motor Enable button on the computer front panel, setting the Pump Start button to "on," and then setting the motor speed in Pump Speed control window.
16. Adjust the cover gas pressure in the sump to ensure smooth LBE circulation without excessive noise and vibration (audio and visual inspection). Add He to sump by opening FV201 and HV203. Remove He by opening FV204. Pressure indicated on PT202.
17. Conduct tests as specified and documented by the Cognizant Engineer.
18. To engage heat exchanger, proceed to the attached Heat Exchanger Operating Procedure.
19. To perform EM flow meter calibration, proceed to the attached Calibration Procedure.
20. To adjust oxygen levels, proceed to the attached Gas Control System Procedure.
21. To leave the loop unattended with the pump operating proceed to Unattended Operation Procedure, Forced Circulation.
22. Turn off pump at completion of tests.
23. Open any LBE valves that were closed to re-configure the loop (except HV119). (We usually open these valves after we've drained, at the same time as HV119…)
24. Activate "Drain" mode from pull-down menu on LabVIEW display.
25. Drain LBE from the loop. Open drain valves FV101 and FV102. Reduce gas pressure in melt tank by opening FV204 to allow LBE to drain. When drain is nearly complete, open gas pressure equalization valves FV205 and FV208. Finally, open HV119 to drain LBE from expansion tank.
26. To maintain the loop heated and ready for later operation, proceed to Unattended Station Keeping Operation Procedure and skip remaining steps in this procedure.
27. Turn off all heaters.
28. Set pressure in system to approximately 20 psig as indicated on PT202, using FV202 and HV204. This will ensure that loop maintains pressure above ambient while it cools to room temperature.
29. Close all 200 series valves except HV212, FV205, FV208 and FV209.
30. Close valves on helium gas bottles.
31. Turn off all 5 breakers on main power panel and turn off pump controller breaker
32. Shut down the DAC program and turn off the DAC system and SRS controllers.
33. Turn off strobe light.

Heat Exchanger Operating Procedure

To start heat exchanger:

This operation is performed when pump is on and LBE is flowing through the loop.

1. Set LBE temperature in the range from 250ºC to 350ºC using band heaters.
2. Ensure that variable area insertion rod on heat exchanger is fully extracted to minimize internal contact area.
3. Set Max value for delT HX to 200°C on the “Presets” page of the program.
4. Open the water supply (HV301) valve. Purge air/steam via the drain valve (HV305). Then simultaneously gradually close HV305 and open HV302 (water return) valves.
5. Monitor water flow via supply (FS307) and return (FT301) flow sensors (should be >13 gpm).
6. To increase heat exchanger cooling capacity gradually turn the crank handle at the top of HX-1 counter clockwise (~12 full turns total from minimum to maximum capacity), while increasing the band heaters set temperatures to hold the loop at the desired mean temperature.
7. Monitor the cooling water flow (FS307, FT301) and temperature difference between water inlet and outlet (delT HX) (the difference should be within $0<\Delta T<20$ºC).
8. When the flow has stabilized set Max value for delT HX to 20°C on the “Presets” page of the program.

To stop heat exchanger:

1. This operation is performed when pump is on and LBE is flowing through the loop.
2. Set Max value for delT HX to 200°C on the “Presets” page of the program.
3. Ensure that variable area insertion rod on heat exchanger is fully extracted to minimize internal contact area.
4. Simultaneously close the water supply (HV301) and return (HV302) valves.
5. Immediately open water drain valve (HV305) to vent the heat exchanger.
6. Gradually open compressed air supply valve (HV321) to purge water from heat exchanger. When complete, close HV321 and leave HV305 open to vent.

Flow Meter Calibration Procedure

1. Turn pump off.
2. Open valve HV116 to calibration tank and close solenoid valve FV103 to calibration tank. Close valve HV115 at entrance to test section. Ensure that main bypass valve HV101 is open. HV101 may have to be partially closed for slower flows to provide faster level increase in the calibration tank.
3. Set pump speed on DAC computer front panel to the value specified by cognizant engineer.
4. Open FV103 to start filling the calibration tank.
5. Monitor and record the rise of LBE level within calibration tank versus time via LT113-116, and record FT101 readout.
6. Upon reaching the upper limit level sensor (LT116 reads closed circuit) in calibration tank, close FV103 and shut down the motor.
7. Once the flow is stopped, re-open FV103 to gravity-drain LBE from calibration tank.
8. Repeat as necessary.
9. When finished, close valve HV116 and open valves HV115 and FV103.

Gas Control System Procedure

This procedure assumes that a freeze plug is in place in the venturi and the LBE is flowing. Use gas system PID from the DELTA design drawings package to determine the valves' names.

1. If necessary, evacuate the cleanup gas line beyond HV208 and refill with desired gas (He, He/H_2, or He/O_2).
2. Ensure cleanup gas pressure is greater than LBE pressure in venturi. PT208 measures gas pressure in cleanup gas line.
3. Open valve HV208 (venturi clean up gas inlet).
4. Turn water off to venturi freeze plug and drain water jacket. Turn on freeze plug heater to unfreeze LBE plug. Monitor level sensors in venturi flange to determine when LBE is liquid and flows down into venturi; adjust pressure to maintain this condition.
5. Turn off freeze plug heater and turn on cooling water to the freeze-plug jacket.
6. Monitor the flow rate of the gas into the system and set a suitable rate. Adjust the gas mixture to maintain a constant flow rate at the given pressure differential while adding the required proportion of O_2/H_2. O_2 will be added (using MCV 202) to attain the desired level in LBE as indicated through the oxygen sensors (output level to be determined during operations). H_2 will be added (using MCV201) during normal operations to reduce the oxygen in LBE. Hydrogen sparging to clean and restore the loop will be performed when noticeable degradation of thermal hydraulic performance is observed.
7. Monitor the venturi level sensors to ensure that the flow is always into the loop, even if the pressure controls on the expansion tank or sump become active.
8. When finished, gradually decrease the gas flow rate. Stop adding gas and slowly release pressure from the gas line so that the LBE backs up into the freeze plug region. Monitor the venturi level sensors to confirm the freeze plug is formed (level showing on bottom two level sensors). If necessary, stop releasing pressure from the gas line when two levels are showing to ensure the freeze plug forms at the desired level.
9. Backfill the gas line to pressure equal or greater than LBE pressure in venturi with He gas.
10. Close valve HV208.
11. Close He/H_2 and He/O_2 bottles.

Unattended Station Keeping Operation Procedure

This procedure puts the loop into a low-pressure, low-temperature heated mode until the next operating cycle is desired. Note: <u>The loop may only be left unattended as per this procedure for time periods of 24 hours or less.</u> This procedure assumes:

- normal operation has been completed
- the LBE has been drained into the Melt Tank.
- a freeze plug is present in the clean-up gas injection zone above the venturi
- regulators on clean-up gas bottles (O_2 and H_2) are in the "off" position
- water to Heat Exchanger is off and has been purged.
- water is on to motor cover and freeze plugs

1. Ensure that all heating zone set points, including the Melt Tank heating zone, are set to 250ºC in the computer control program.
2. Ensure that pump controller power is off.
3. Close hand valve HV116 to calibration tank. Open all other 100-series hand valves on LBE piping except HV117 and HV118 (HV101, HV102, HV105, HV106, HV107, HV108, HV109, HV110, HV111, HV112, HV113, HV114, HV115, and HV119). [Note: HV103 and HV104 do not exist.]
4. Open solenoid valves FV101, FV102, FV103, FV205, FV208 and FV209.
5. Ensure that hand valves HV212 and HV215 are open. Open hand valve HV203 partially to 4 turns. Close all other 200-series hand valves on gas/vacuum system (HV201, HV202, HV204, HV205, HV206, HV207, HV208, HV209, HV210, HV211, HV213, HV214).
6. Set the loop pressure set point in the computer control program to 13 psia as indicated on PT201 and controlled with FV201.
7. Set the data output interval in the computer control program to 60 seconds.
8. Perform **Routine Inspection of the System**.
9. Turn the door interlock key switch to "normal."
10. Set the pressure regulator on the helium cover gas bottle farm to 20 psig. Ensure an adequate supply of helium is present in helium cover gas bottle farm.
11. Ensure warning signs are posted on all 3 entrances to the DELTA loop area indicating "Hot Surfaces" and "Stored Energy" hazards. Ensure contact names and numbers of emergency personnel and "on-call" system operators are appropriately displayed on all 3 entrances.
12. Activate "LBE in Melt Tank" mode from pull-down menu on LabVIEW display.
13. Ensure that computer control program is controlling loop temperatures and pressure to the set point values indicated above.
14. If Station Keeping Operation is desired for a period of time greater than 24 hours, the cognizant engineer will identify a system operator or operators who will check on the loop on a daily basis and record this information in the log book.

Unattended Operation Procedure, Forced Circulation

This procedure puts the loop into a fully functioning, unattended mode of operation for the purpose of continuous, long-term testing. Note: <u>The loop may only be left unattended as per this procedure for time periods of 24 hours or less.</u> This procedure assumes:

- pump is on and set at the desired flow rate
- trace and band heaters are on and set at desired set points
- temperatures and pressures have reached a steady-state condition
- a freeze plug is present in the clean-up gas injection zone above the venturi
- regulators on clean-up gas bottles (O_2 and H_2) are in the “off” position
- water to heat exchanger is on and variable area handle is set as desired
- water is on to motor cover and freeze plugs

1. Designate the Cognizant Engineer who will be responsible for checking the status of the loop (remotely via the internet). Record the required intervals of these status checks in the logbook.
2. Ensure that the cover gas pressure in the melt tank is at least 38 psi above the pressure in the sump tank.
3. Ensure that hand valves HV212 and HV215 are open. Open hand valves HV203 and HV204 partially. How much to open these valves is defined by the Cognizant Engineer. Close all other 200-series hand valves on gas/vacuum system.
4. Ensure an adequate supply of helium is present in helium cover gas bottle farm. (at least two full bottles are connected and two full spares are available)
5. Switch from “User Controls Gas Valves” to “Program Controls Gas Valves” on the Gas System page of the DAC program display.
6. Set the Sump Tank pressure set point (“PT201 Control”) at least 38psi higher than the Melt Tank pressure set point (“PT202 Control”) in the computer control program.
7. Activate the data-to-internet system and verify that system is functioning.
8. Designate the System Operators who will be on call and for what period of time (24 hours, weekend, etc.).
9. Activate the auto-paging system and perform a system check by sending a test page to System Operators (designated in previous step). This test page will require that System Operators contact the Cognizant Engineer immediately to verify that their pagers are functioning.
10. Ensure that computer control program is controlling loop temperatures and pressures to the set point values.
11. Set the data output interval in the computer control program to 60 seconds.
12. Perform **Routine Inspection of the System**.
13. Turn the door interlock key switch to “normal”. Remove the keys from the switch and store them in a different location on site, accessible to the system operators.
14. Ensure warning signs are posted on all 3 entrances to MTL area indicating “Unattended Operation,” “Hot Surfaces,” and “Stored Energy” hazards.
    - Ensure contact names and numbers of emergency personnel and “on-call” system operators are appropriately displayed on all 3 entrances.

- If Unattended Operation is desired for a period of time greater than 24 hours, the Cognizant Engineer will identify a system operator or operators who will check on the loop on a daily basis and record this information in the log book.
- Daily checks of the loop while it is in Unattended Operation will consist of steps 9 through 13 of this procedure.

15. Upon receiving a page with a SCRAM message, call the DELTA loop telephone (665-0768) and send acknowledgement command to the Autodialer only if you can come to the loop.
    - Then check the autodialer status or the messages on the loop voice mail.
    - If for any reason you are unable to come, page a backup operator.
16. At the DELTA loop after a SCRAM action was activated and it is safe to do so perform “Routine Inspection of the System”.
17. System operators make a decision whether to restart the operation, leave the loop in heated unattended station keeping mode or to let the loop cool down. Corresponding procedures must be followed in either case. Record the SCRAM condition and the decision in the logbook.

Manual Shutdown of the Loop in Case of Computer Control Failure

Note: The watchdog timer will shut down the loop if no reset signal has been received from the computer for 10 seconds.

1. If power is on but the computer is frozen, press SCRAM button, then force computer restart or shut down (Press Ctrl, Alt, Delete buttons simultaneously), when shut down screen appears choose restart or shut down. The loop will shut down by itself as the result of SCRAM.
2. After computer restart investigate reasons for computer malfunction.
3. If ready to start operating again refer to “Pre-start Checklist” and to the appropriate operating procedure.

Scram Operation in Case of Electricity Disturbance or Shut-off

1. If during an operation, a temporary electricity disturbance (e.g. power line spikes) trips parts of the loop (e.g. motor, actuated valves, etc), but the computer control is unaffected (e.g. because the computer is on UPS), initiate emergency data collection.
2. If power is restored, restart operations according to the "Normal Operating Procedure".
3. If power outage is sustained, go to cold station keeping and monitor status (DAC is on UPS).

Scram Operation in Case of Off-Normal or Off-Design Events, with Computer Running

The computer will automatically shut down the loop operation in the event of any of the Emergency Shutdown Conditions listed in “Critical Controls in DELTA DAC Program” in the HCP.

1. Use the SCRAM button on the DAC computer main panel to shut down but to continue recording data. In addition red round SCRAM buttons are located near the loop access doors on every level.
2. Assess the safety of entering or remaining in the building and the DELTA loop experimental area. If conditions at the DELTA loop or in the building are unsafe, do not undertake any of the following steps. Follow the emergency procedures.
3. System Operators perform “Routine Inspection of the System”. Two-man rule has to be implemented when entering the enclosure: at least two system operators go inside the loop if entry is necessary.
4. Based on the SCRAM cause the system operators make a decision whether to restart the operation. Follow Pre-start Checklist and Normal Operating Procedure.

Maintenance and Repair Operation Inside of the Enclosure

1. Follow all steps in Routine Inspection of the System.
2. Follow Laboratory Lockout/Tagout procedures for operations on appropriate energized and pressurized systems and components.
3. Follow all Laboratory pertinent procedures for construction operations.
4. Wear proper PPE as described in the HCP.
5. If LBE is present in the drain pan or/and on loop components, allow it to cool down and solidify. LBE must be collected and put away in a designated area if it is to be reused in the loop or put away to the Satellite Storage Area. Use “Waste Stream” procedure in the HCP. LBE clean up must be done before any work is to be performed in the loop enclosure.
6. If there is loose (black) oxide powder visible to the naked eye, wear latex gloves to collect a small sample, store it in a sealed plastic bag, and note time and location for future analysis. Consider wearing a respirator.
7. Use HEPA vacuum cleaner to collect any loose lead contaminated dust or particles. Use wet tissues to wipe clean any exposed and accessible parts, discard used tissues in sealed plastic bags, label lead/lead oxide waste, date, operation and responsible person, and store in the Satellite Storage bins (follow Waste Stream procedure in the HCP).
8. If operation includes cutting and/or welding of pipes with potential solid LBE inside, see “Cutting and Welding Parts exposed to Lead-Bismuth”
9. If operations include opening any of the flanged pipe connections or flanged sensor feed-throughs see “Removal and Replacement of Flanged Pipe Sections”.

Cutting and Welding Parts Exposed to Lead-Bismuth.

This includes piping, vessels, oxygen sensor fittings, and pressure transducer fittings.

1. Ensure that the pipe is below 50°C.
2. Ensure there is no noticeable black powder around or on the section to be removed. If there is some, wearing respirators clean it up first using the HEPA vacuum cleaner and/or wet tissues.
3. Place a catch device (pan, plastic sheet, etc.) under the section to be removed to catch any lead pieces that may fall out.
4. Prepare the HEPA vacuum cleaner. Place the HEPA Vacuum cleaner nozzle near the cutting area to catch the dust and shavings.
5. Cut using a power saw or a power grinder. Employ the safety rules for using these power tools.
6. Follow the normal precautions for TIG welding.
7. Supply a flow of Argon gas in place of air during the welding operations. Argon will flow into the pipe, exit through other openings into the enclosure and will be vented via the enclosure venting system.
8. Clean the area after the job is finished using the HEPA vacuum and/or wet tissues. Consider the need for respirators.

Removal and Replacement of Flanged Pipe Sections.

1. Ensure that the pipe is below 50°C.
2. Ensure there is no noticeable black powder lead oxide around or on the section to be removed. If there is some, wearing respirators cleaned it up using the HEPA vacuum cleaner and/or wet tissues.
3. Place a catch device (pan, plastic sheet, etc.) under the section to be removed to catch any lead pieces that may fall out.
4. Prepare the HEPA vacuum cleaner.
5. Try to prevent the pipe section from falling while you are taking out the bolts. For example: leave one or more bolts and nuts connecting the flanges on either side while the rest of the bolts are taken out.
6. Remove the bolts and take out the section stopping to clean up lead if necessary. If black powder lead oxide appears, stop. Further work will be conducted wearing a respirator.
7. Remove the pipe section.
8. If you cannot remove the pipe section, solidified lead-bismuth may be inside the pipe and it may have to be cut or melted locally. Follow “Cutting and Welding Parts Exposed to Lead-Bismuth”.
9. Place the HEPA Vacuum cleaner nozzle near the cutting area to catch the dust and shavings.
10. Cover the exposed ends of the pipe if you do not intend to put a new section in right the way.
11. Install the new section and retighten flange bolts according to the flange bolt torque requirements specified by the Cognizant Engineer.

Flange/Bolt Maintenance Schedule

Flanges are used throughout the test loop to facilitate inspections and modifications. The following maintenance schedule is intended to improve and track the performance of the flanges by keeping them tight and observing points of likely failure, as observed by repeated elongation or loosening of bolts. This maintenance schedule is intended as a minimum level or inspection.

1. Verify bolt torque prior to first heating to temperature (20 ft-lb at all 300 lb, 2 inch flanges).
2. Check bolt torque after first heating to temperature.
3. Any loose bolts found during Step 2 should be retorqued after each heating to temperature, up to the 5th heating.
4. After 5th heating to temperature, check all bolt torques. At this point, any bolts that have been consistently loose must be evaluated for safety and integrity. Consider the following options:
   - Replace with inconel bolt, finger tight at room temperature.
   - Replace flange with welded joint.
   - Replace bolt with new stainless steel bolt and continue to monitor.
5. After 10th heating to temperature, check all bolt torques.
6. While continuing to monitor problem areas, retorque all bolts after increasingly long run times, starting at 20 hrs, then 50, 100, and 500 hrs.
7. At any time a significantly higher operating temperature (50ºC increase) is reached than has been the norm for some period of time, increase the frequency of bolt checks to identify potentially new problem areas.

9. Required Attachments

Attachment 1: DELTA Emergency.

EMERGENCY PROCEDURES FOR DELTA LOOP EXPERIMENTS

Attachment 2: External Emergency Shut Down Procedure.

EMERGENCY SHUT DOWN PROCEDURE

Attachment 3: DAC Critical Controls.

CRITICAL CONTROLS FOR DELTA DAC PROGRAM

Attachment 1: DELTA Emergency.

EMERGENCY PROCEDURES FOR DELTA LOOP EXPERIMENTS
(Post in work area)

FOR FIRE, SERIOUS INJURY OR OTHER SERIOUS EMERGENCY
CALL 911

1. If SCRAM was not activated, press a SCRAM button on the program front panel (at the top), on the DAC cabinet or on the enclosure at any of the doors.

2. If it is safe, the system operators perform “Routine Inspection of the System” in DELTA Procedures.
3. If a significant liquid metal leak (larger than a quarter of the drip pan area) is apparent, and if it is safe to approach manual gas valves panel, close all gas supply valves (HV203, HV204,), relieve pressure through vent valves HV205 and HV206, and drain the water as described in Drain Down Procedure (pg 7 of operations).
4. If needed notify other system operators of the status.
5. If needed post signs indicating the hazards at the DELTA loop entrances.
6. Inform LANSCE-3 group management and the group management of involved personnel.

Attachment 2: External Emergency Shut Down Procedure.

EMERGENCY SHUT DOWN PROCEDURE

In case of building evacuation, hazardous malfunctions or other urgent circumstances:

PRESS SCRAM BUTTON AT THE TOP OF THE COMPUTER DISPLAY TERMINAL

NOTIFICATION LIST

Name	**Office**	**Pager**
Valentina Tcharnotskaia	5-9375	104-5648
Mike Madrid	5-4964	104-7574
Ning Li	5-6677	996-4575
Bruce Takala	5-2029	104-8827

In case of electrical accident also notify:

Group ESO:		
Dave Harkleroad	5-0501	996-3497
Group management:		
Steve Wender	7-1344	104-2185

LANL Emergency Management Office: **7-6211 or 7-7080 (after hours)**

LANSCE FM-D (On Call): **664-7466 (pager)**
LANSCE ES&H: **5-4666 or 5-9822 or 5-2584**

Note: For injuries not requiring ambulance or emergency response personnel, transport the injured to ESH-2, TA-3 SM-409 or to the Los Alamos Medical Center.

Attachment 3: DAC Critical Controls.

CRITICAL CONTROLS FOR DELTA DAC PROGRAM

	Name	**Signature**	**Date**
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Reviewer			
Revision	1	Updated for unmanned operations	
	2	Updated for access during operations and OJT description	10/2/02

CRITICAL CONTROLS FOR DELTA DAC PROGRAM

These conditions apply during operations with the pump running.

Condition	Necessary Reaction
1. Sump Tank level is at 12” during operation with pump running.	SCRAM(1)
2. Expansion Tank level is at 13.75”. at 12.5”.	SCRAM Warning(2)
3. Expansion Tank level is at 1.625”. at 5”.	SCRAM Warning
4. Third level reached in the venturi.	Warning
5. Forth level reached in the venturi.	SCRAM During oxygen control ops, Drain after 5 cycles
6. High gas pressure: PT201, PT202, PT203, PT204, PT205 ≥80psig	SCRAM Warning on increasing pressure
7. Low gas pressure when the pump is running: PT201, PT202 ≤ 10psig	SCRAM Warning on decreasing pressure
8. High liquid metal pressure: PT101, PT102, PT104 ≥80psig	SCRAM Warning on increasing pressure
9. Enclosure pressure PT206 (or PT207)≤ 0.2mm Hg	SCRAM
10. Actuated drain valves are open.	Drain(3)
11. MFM shows no flow when the pump is on.	SCRAM
12. Water flow speed ≤1.5GPM to pump motor cooling jacket.	Drain
13. Water flow speed ≤ 0.5GPM to Oxygen sensors’ cooling jackets.	SCRAM
14. Water flow speed ≤ 0.01GPM to venturi’s cooling jacket.	SCRAM
15. For operations using Heat Exchanger: Water flow speed ≤ 10GPM to the Heat Exchanger	SCRAM

Condition	**Necessary Reaction**
16. High temperature(4): 330^0C – T137; (For uniform temperature runs this thermocouple's corresponding max temperature is 430^0C) 430^0C – T108, T109, T112, T119, T120, T121, T122, T124, T126, T127, T128, T144, T145, T146, T147, T148, T149, T150, T151, T152, T155, T156, T157, T158, T159, T160, T167, T168, T197, T198, T199, T201, T202, T206, T207, T210, T211, T212, T213, T228, T229, T901; 480^0C – T104, T106, T110, T113, T114, T117, T118, T129, T130, T136, T141, T142, T143, T153, T154, T161, T162, T163, T164, T165, T166, T169, T170, T175, T176, T178, T181, T182, T183, T184, T185, T186, T203, T204, T205, T208, T209, T902, T905; 530^0C - T116, T131, T132, T133, T134, T138, T139, T140, T171, T172, T173, T174, T177, T178, T179, T180, T187, T188, T189, T190, T191, T192, T193, T194, T195, T196, T214, T215, T216, T217, T218, T219, T220, T221, T222, T223, 224, T225 T226, T227, T903, T904 (The independent temperature monitoring devices are set at 20^oC higher max temperatures)	SCRAM Warning on increasing temperature
17. Temperature by thermocouples listed in 14 is ≤ 150^0C.	SCRAM Warning on decreasing pressure
18. Heat Exchanger increase in water temperature is ≥ 20^0C.	SCRAM
19. Motor temperature T200, T218 ≥80^0C.	Drain
20. A SCRAM on the loop is activated.	SCRAM

Condition	Necessary Reaction
21. Power failure.	Watchdog timer shuts down the whole system.

[(1)] - SCRAM means that power to the heaters, valves and the pump controller is shut off. The pump stops, the heaters turn off and the valves go to their default states that promote drainage of liquid metal from the loop into the Melt Tank. DAC program stays on and records data.

[(2)] – Warning means a text warning appears in the warning window on the “Main” and “Intermediate Data” panels of the DAC program.

[(3)] - Drain means that the pump stops, drain valves open, gas pressure equalizing valves open, pressure set points equalize and heaters stay on.

[(4)] - The Cognizant Engineer can adjust Maximum temperature values. Future experience may show that different maximum temperature values are appropriate.

In all of the above conditions only the automatic necessary actions are given as responses to the conditions. The system operator makes the decision about the next steps to be taken in each case. The system operator may make a decision to shut down the whole operation if he/she deems it necessary.

10. System Operators and Cognizant Engineers

Cognizant Engineers on the project are:

Curtt Ammerman
Ning Li
Keith Woloshun
Valentina Tcharnotskaia.

Persons eligible to be System Operators, provided they have training and OJT described in 6:

Name	Office	Pager
Ning Li	5-6677	996-4575
Mike Madrid	5-4964	104-7574
Valentina Tcharnotskaia	5-9375	104-5648
Keith Woloshun	5-6822	104-4842

All System Operators must sign the acknowledgement log below.

Acknowledgment Log

I have read this Hazard Control Plan.

NAME	SIGNATURE	DATE